

GROUNDWATER INVESTIGATION
TACOMA, WASHINGTON PLANT SITE
PHASE I

INTRODUCTION

This report summarizes the findings of the Phase I groundwater study that was conducted at the Tacoma, Washington plant between June and December, 1979. The purpose of the investigation was to evaluate the groundwater pollution potential of liquid and solid industrial waste materials that are contained on plant property. The study was made at the request of Robert L. Hall, Manager - Safety, Health & Environmental Control, Hooker Chemicals & Plastics Corp., Niagara Falls, New York.

The Tacoma plant is situated between East 11th Street and Commencement Bay. It is bordered on the northeast by Hylebos Waterway and on the southwest by Alexander Avenue, as is shown in Figure 1. Most of this heavily industrialized area has been modified and raised above bay level with dredged materials which consist mainly of silt, and fine to medium sand of alluvial or marine deposit origin. Underlying the modified lands are undisturbed alluvial or marine formations of these same fine-grained deposits.

Precipitation recharge to such materials readily moves downward to the water table, and from there outward to some

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natural groundwater discharge zone along the sides or bottom of an adjacent, deeply dredged waterway. In such a geohydrologic environment, pollution from surficial sources may also follow this same hydrologic cycle. For this reason, the Phase I investigation was designed to obtain a preliminary assessment of the groundwater flow system within the surficial deposits beneath the plant grounds; as well as a qualitative appraisal of the type, extent, and relative order of magnitude of any groundwater pollution which might be occurring from suspected pollution sources on plant property.

BACKGROUND INFORMATION

Chlorine and caustic soda have been produced at the Tacora plant since 1929. Industrial solvents also were made from 1948 until 1973, but since that time all of the solvents production equipment has been dismantled and removed from the property.

The primary pollutants associated with the chlorine and caustic-soda production processes are: sodium chloride, NaCl ; sodium hydroxide, NaOH ; calcium, Ca ; magnesium, Mg ; a higher than normal pH; and an effluent that is brownish-colored and often elevated in temperature. The pollutants associated with the old industrial solvents area are chlorinated organics such as: trichloroethylene, C_2HCl_3 ; perchloroethylene, C_2Cl_4 ; tetrachloroethane, $\text{C}_2\text{H}_2\text{Cl}_4$; pentachloroethane, $\text{C}_2\text{Cl}_5\text{H}$; hexachloroethane, C_2Cl_6 ; chloroform, CHCl_3 ; and carbontetrachloride, CCl_4 .

— In the past, most of the waste materials derived from the various chemical-production processes were buried on plant

property. Since about 1972 all waste materials generated have been transported away from the plant grounds for appropriate disposal.

MONITORING-WELL NETWORK

To accomplish study objectives, nine monitoring-well locations, spaced on a rough grid pattern throughout plant property as shown in Figure 2, were selected to obtain the required water-table and water-quality information. Initially, only one shallow monitoring well was planned for each location. However, geochemical data obtained during the drilling of the first test hole (at site 4 in the old solvents plant area) dictated that two monitoring wells at each site would have to be installed.

The test hole at site 4 penetrated fine to medium sand from land surface to about 25 feet, a dense silty layer from 25 to 30 feet, and fine to medium sand from 30 to 50 feet. As the hole was drilled, a strong hydrocarbon odor was noted within the 10-foot unsaturated earth-material section above the water table. Subsequent analyses of groundwater samples collected every 5 feet below the water table to final depth also indicated that hydrocarbon pollution might be present throughout that vertical segment of the aquifer. Because of these findings, the initial study plan was revised to include a shallow and a deep monitoring well at each station: one above the silt zone at a depth of about 25 feet; the other below the silt bed, at a depth of about 50 feet.

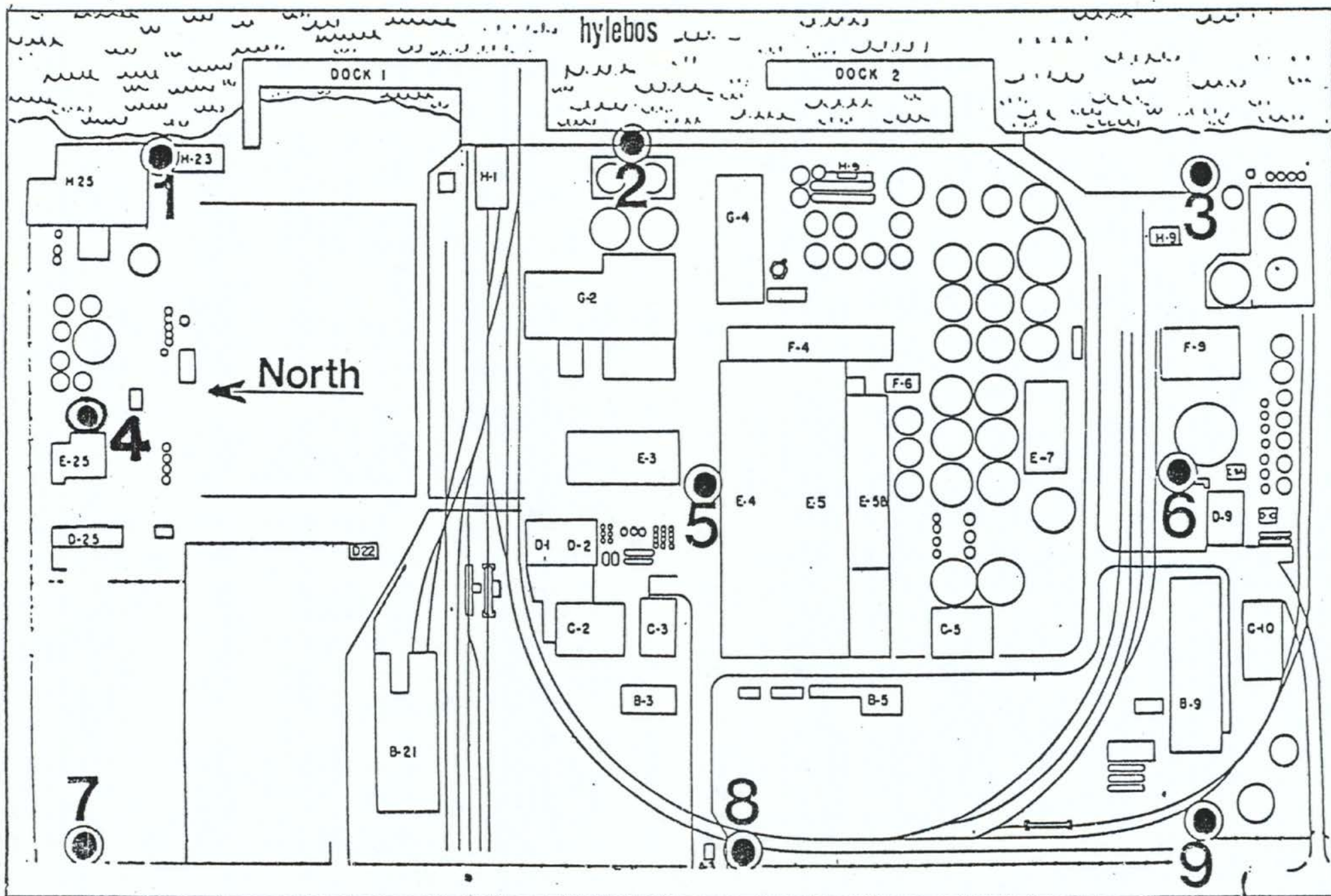


FIGURE 2. MONITORING SITE LOCATIONS.

The 18 monitoring wells finally placed were installed by the drilling firm, Subterranean, Inc., under the field supervision of Mark Utting of Hart, Crowser & Associates. A report prepared by Mark Utting, which includes all of the geohydrologic information he collected, is attached. Final well development and sampling activities, and in-plant analyses of the groundwater samples collected from each monitoring well were under the direction of Don Oderkirk. Their data form the base for the following evaluation of groundwater conditions in the plant-site area.

GROUNDWATER FLOW SYSTEM

As the level of Hylebos Waterway rises and falls with the tide, the discharge of groundwater from the plant grounds to that surface-water body must vary as well. During low tide periods, when the waterway exerts minimal backpressure on the surficial aquifer system, water-table gradients steepen toward the waterway and maximum groundwater flow to that discharge point can occur. On the other hand, as high tides take place and maximum backpressure is exerted on the aquifer, the water table rises, gradients reverse, and groundwater beneath the plant grounds is forced to move landward until the next low tide gradient reversal permits it to flow once more toward Hylebos Waterway. Under such tidal influences, any pollution contained in the aquifer also might follow a similar migration pattern from the initial point of entry to its eventual discharge area along the Waterway.

To obtain a total appraisal of the groundwater flow system in the area, the shape and slope of the water table under all degrees of tidal influence is required. However, during the time allotted for this Phase I preliminary study, it was possible to obtain an approximate definition of only high-tide and low-tide flow conditions. The seasonal high high and low low tide periods of November 19, 1979 were selected for investigation. Water-table contour maps, drawn from water-level measurements made in the shallow and deep monitoring-well networks during these particularly extreme, tidal-fluctuation periods are shown in Figures 3 through 6. For comparative purposes, these figures, as well as others that are chemically related, are presented in unattached form in the appendix of this report.

In evaluating or comparing the various water-table maps included, it must be realized that groundwater movement always must be perpendicular and downgradient to the water-table slope. Also, it must be understood that the contour maps included were constructed using a minimal data base, and for this reason may be only rough approximations of the actual shape and slope of the aquifer surface at any specific location. However, if considered in proper context, the maps do reveal several most significant facts.

For example, all of the four maps show a persistently high water-table elevation in the vicinity of monitoring station 5, and an equally obvious groundwater mound along Alexander Avenue. A primary east-west pattern of groundwater movement is reflected

in all of the maps, and secondary north and south components of flow are inferred on both of the shallow water-table maps as well as on the high-tide map of the deep aquifer unit. In addition, the maps show that a downward groundwater flow component prevailed throughout the plant property during both of the tidal events considered.

The significance of all of these flow-direction characteristics becomes obvious if the chemical-quality data in Figure 7 is first compared with the various potential sources of pollution on plant property (Figures 8-10), and then overlaid in turn on each of the water-table contour maps. From such a comparison, the following hypotheses appear realistic.

1. The persistently high water-table elevation in the vicinity of monitoring site No. 5 apparently is caused by a continuous leakage source located somewhere within the cell-house complex.
2. Sodium-hydroxide pollution from this source migrates in all compass directions from its point of origin, but moves primarily downward to the deeper segment of the surficial aquifer system, and then eastward and northwestward from there towards sampling stations 2 and 7.
3. The groundwater mound along Alexander Avenue is a permanent water-table divide between the Hylebos and Blair Waterways, thus obstructing westward migration of plant-derived groundwater pollution beyond that street.

4. Organic contaminants from the old industrial solvents area have moved eastward toward Hylebos Waterway and westward towards Alexander Avenue, through both the shallow and deep portions of the aquifer system.
5. Some groundwater contamination from this area also may have migrated northward, off plant property.
6. Significant below-ground leakage, or overflow seepage, from the salt pad facility appears to be migrating through both the shallow and deep aquifer segments, with the major component of flow toward sampling station No. 1, and a secondary, though sizeable, flow component toward sampling station No. 7.
7. All parts of the surficial aquifer contain salty or brackish water that is mostly derived from tidal-induced sea-water infiltration.
8. The old lime-pond sludge disposal areas now appear to be contributing only minimal amounts of pollution to the surficial groundwater reservoir.

RECOMMENDED CORRECTIVE ACTIONS

In a first-priority order of correction procedures to employ at the Tacoma plant, elimination of the following three groundwater-pollution sources on plant property should be addressed:

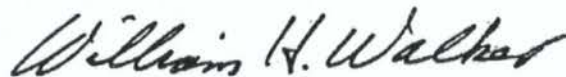
- a) Environmental isolation of the abandoned industrial solvents area in the vicinity of sample station No. 4.

- b) Location and elimination of leakage from all underground caustic-soda tanks, transmission pipes and conduit trenches in the cell-house area.
- c) Rehabilitation and continuing proper maintenance of the salt pad facility.

If these three major pollution sources are eliminated, it is predicted that practically all of the groundwater pollution now being derived from the plant site will cease. Correction of problem areas b) and c) probably can be accomplished solely by in-house action. However, environmental containment of the abandoned solvents plant area will require a considerable amount of additional pre-closure study, evaluation, and corrective action by outside consultants who are specialists in this work.

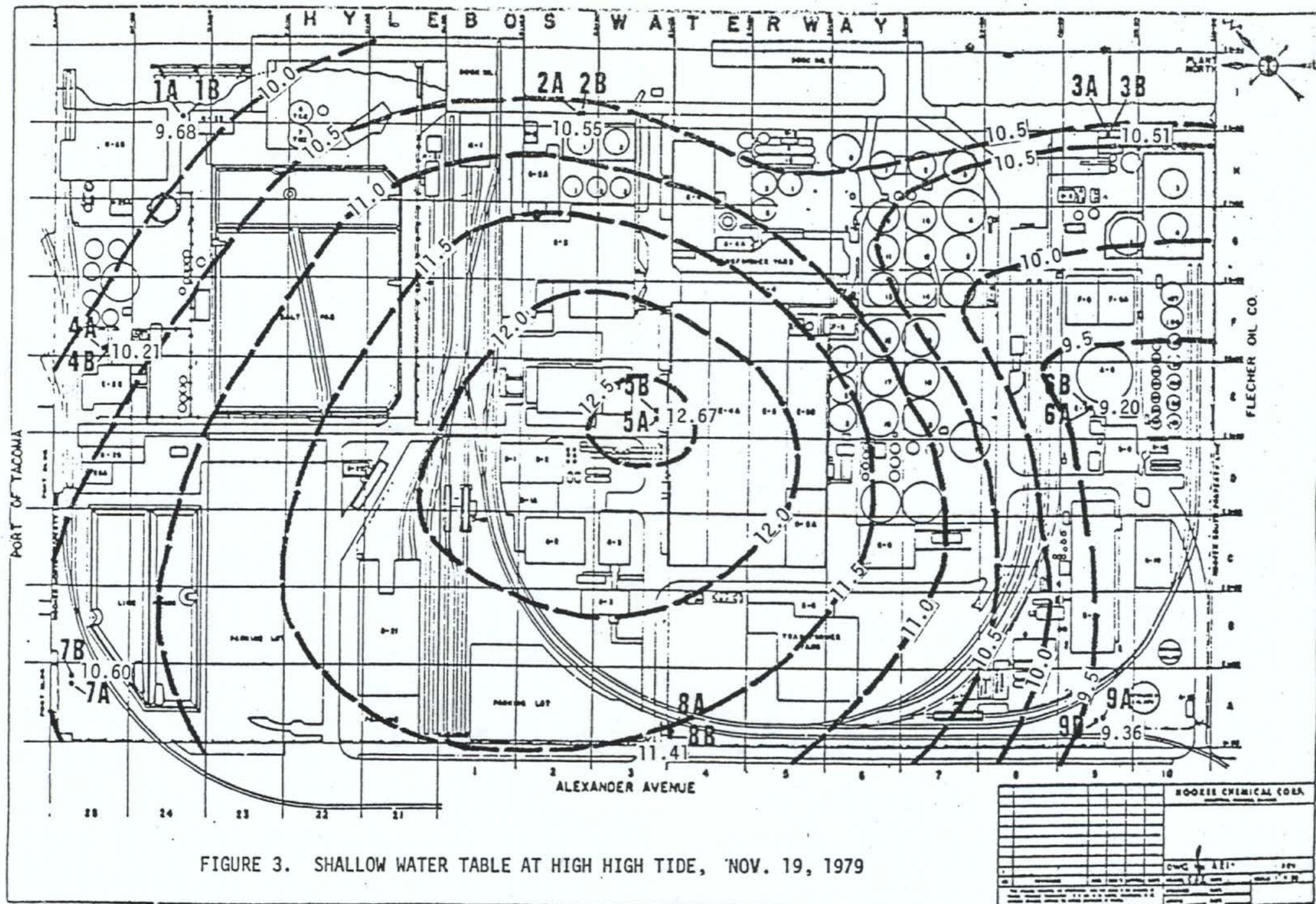
Respectfully submitted,

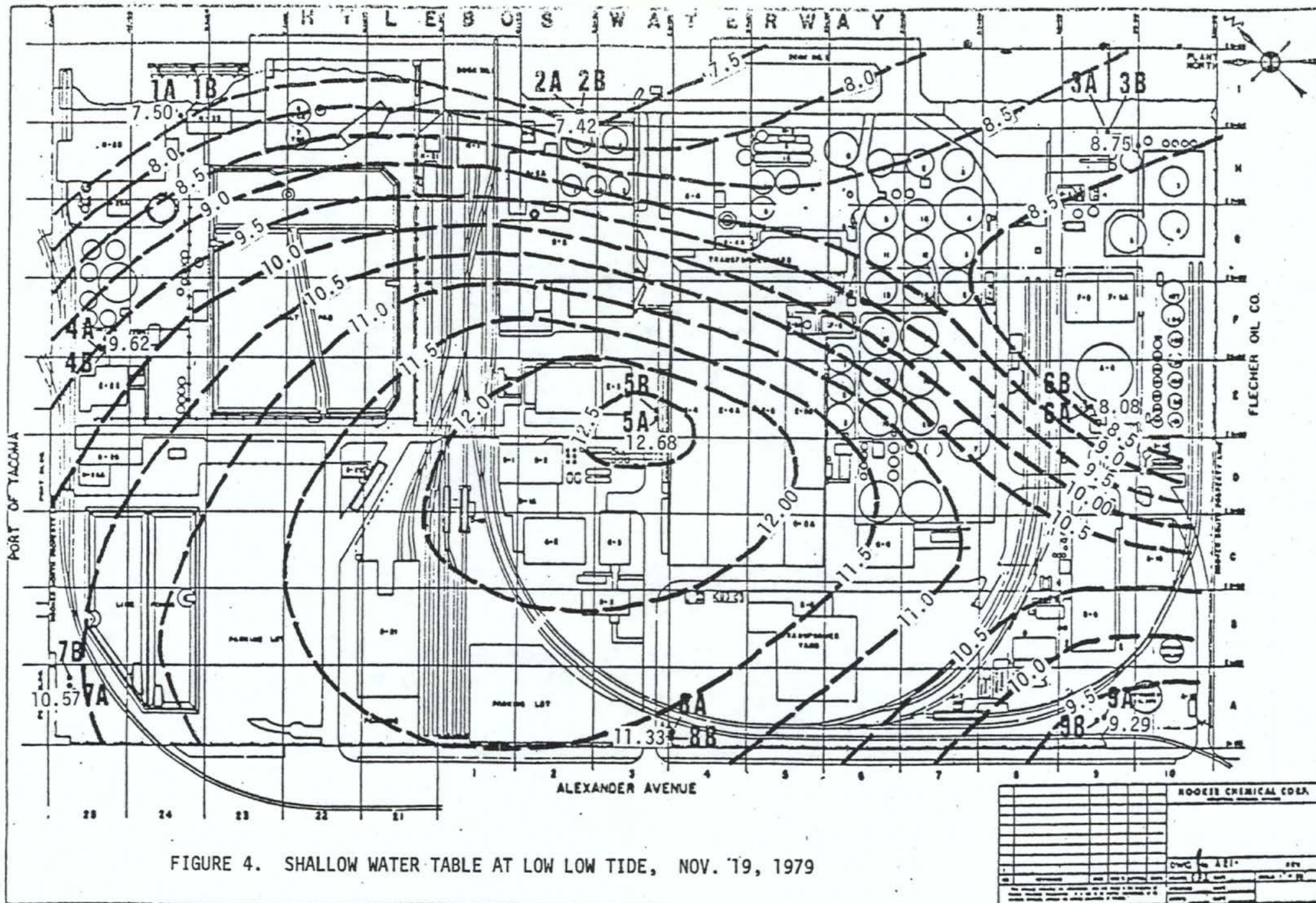
WALKER WELLS, INC.



William H. Walker, President

December 10, 1979





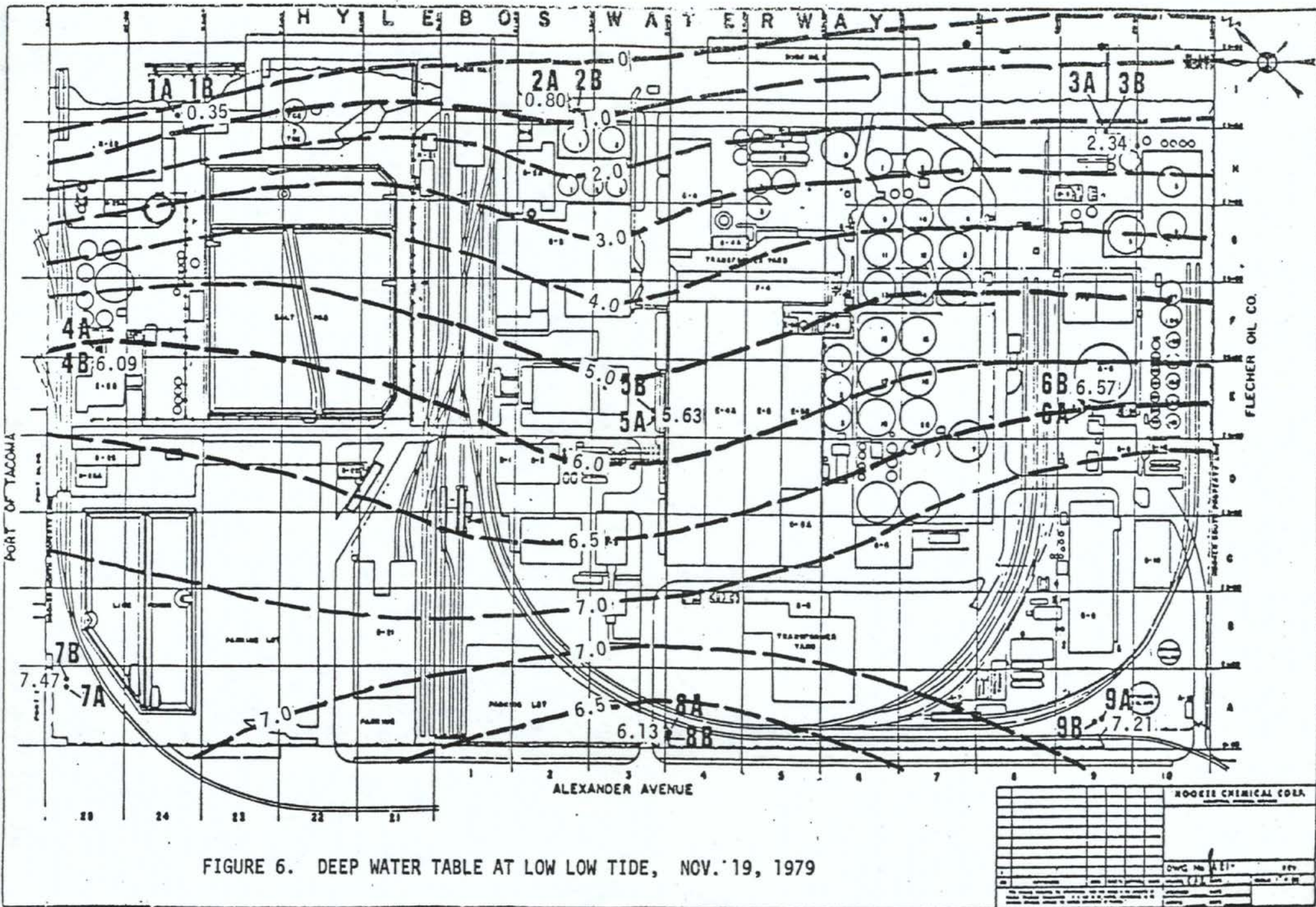


FIGURE 6. DEEP WATER TABLE AT LOW LOW TIDE, NOV. 19, 1979

Organics 4
NaCl 67,300
NaOH 13,300
Ca 16
Mg 14
pH 10.4
color Brown

B

1

Organics 217
NaCl 108,200
NaOH 1,700
Ca 396
Mg 10
pH 8.8
color Lt Brn

A

Organics <.05
NaCl 23,400
NaOH 330
Ca 324
Mg 581
pH 7.6
color Clear

B

2

Organics <.05
NaCl 2,900
NaOH 73,700
Ca 28
Mg 14
pH 12.0
color Dk Brn

A

Organics <.05
NaCl 5,300
NaOH ND
Ca 876
Mg 166
pH 6.4
color Lt Brn

B

3

Organics <.05
NaCl 17,600
NaOH 2,000
Ca 240
Mg 317
pH 8.4
color Lt Brn

A

Organics 377
NaCl 19,300
NaOH ND
Ca 830
Mg 46
pH 6.5
color Yellow

B

4

Organics 537
NaCl 26,300
NaOH ND
Ca 5,380
Mg 384
pH 6.3
color Yellow

A

Organics <.05
NaCl 21,600
NaOH 6,300
Ca 54
Mg 15
pH 10.5
color Clear

B

5

Organics <.05
NaCl 39,200
NaOH 83,300
Ca ND
Mg ND
pH 11.5
color Dk Brn

A

Organics <.05
NaCl 2,900
NaOH 11,300
Ca 145
Mg 222
pH 10.9
color Brown

B

6

Organics <.05
NaCl 9,400
NaOH 670
Ca 116
Mg 146
pH 7.8
color clear

A

Organics 57
NaCl 56,700
NaOH 1,700
Ca 372
Mg 17
pH 9.1
color Lt Brn

B

7

Organics 78
NaCl 43,900
NaOH 330
Ca 1,900
Mg 250
pH 7.7
color Lt Brn

A

Organics <.05
NaCl 2,300
NaOH ND
Ca 72
Mg 10
pH 7.6
color Clear

B

8

Organics <.05
NaCl 18,000
NaOH 1,000
Ca 16
Mg 36
pH 8.4
color Lt Brn

A

Organics <.05
NaCl 1,200
NaOH 12,700
Ca ND
Mg ND
pH 11.4
color Lt Brn

B

9

Organics <.05
NaCl 1,200
NaOH 1,300
Ca 16
Mg 38
pH 8.4
color Lt Brn

A

FIGURE 7. CHEMICAL QUALITY OF GROUNDWATER IN SHALLOW (B) AND DEEP (A) PARTS OF AQUIFER

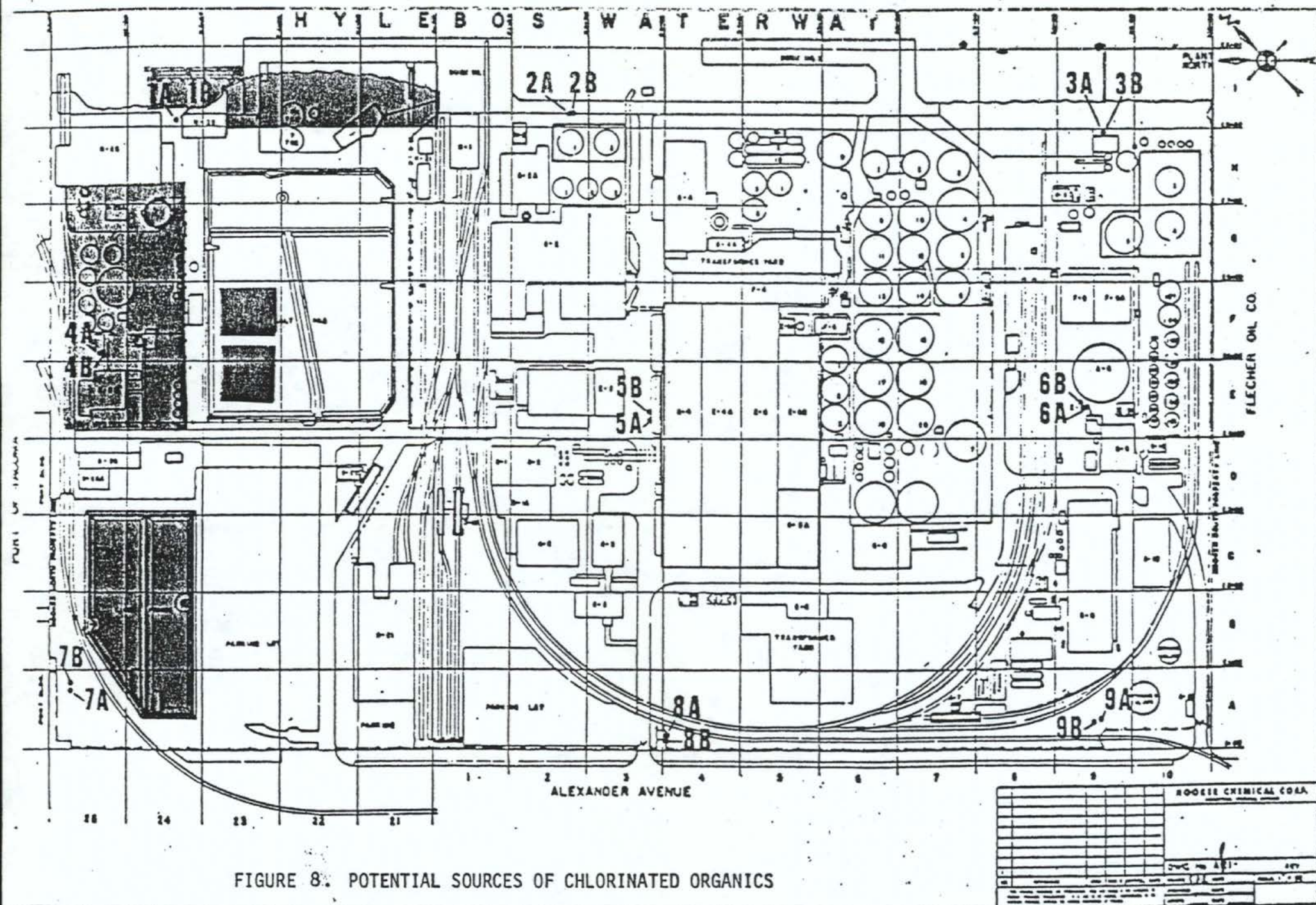


FIGURE 8. POTENTIAL SOURCES OF CHLORINATED ORGANICS

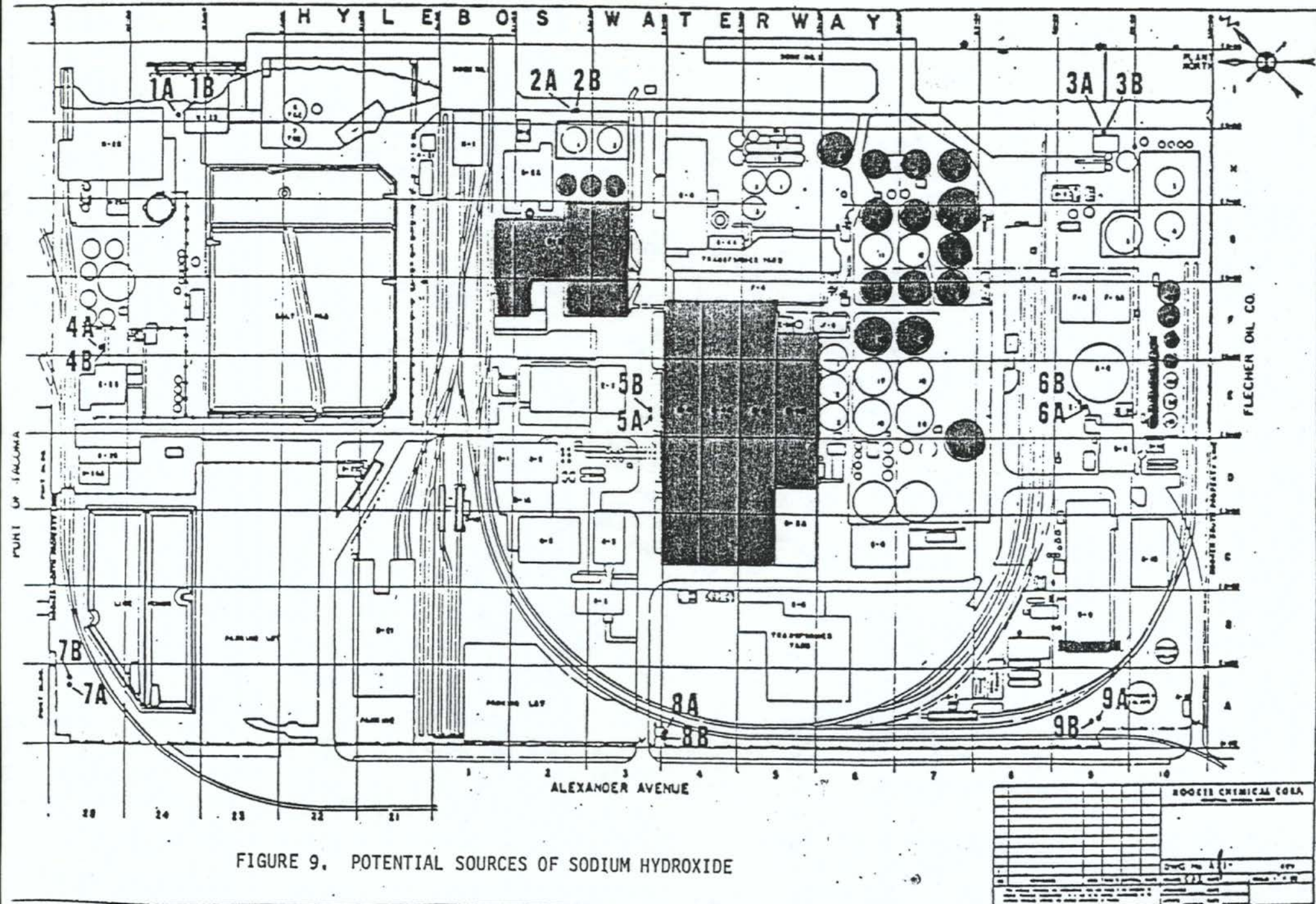
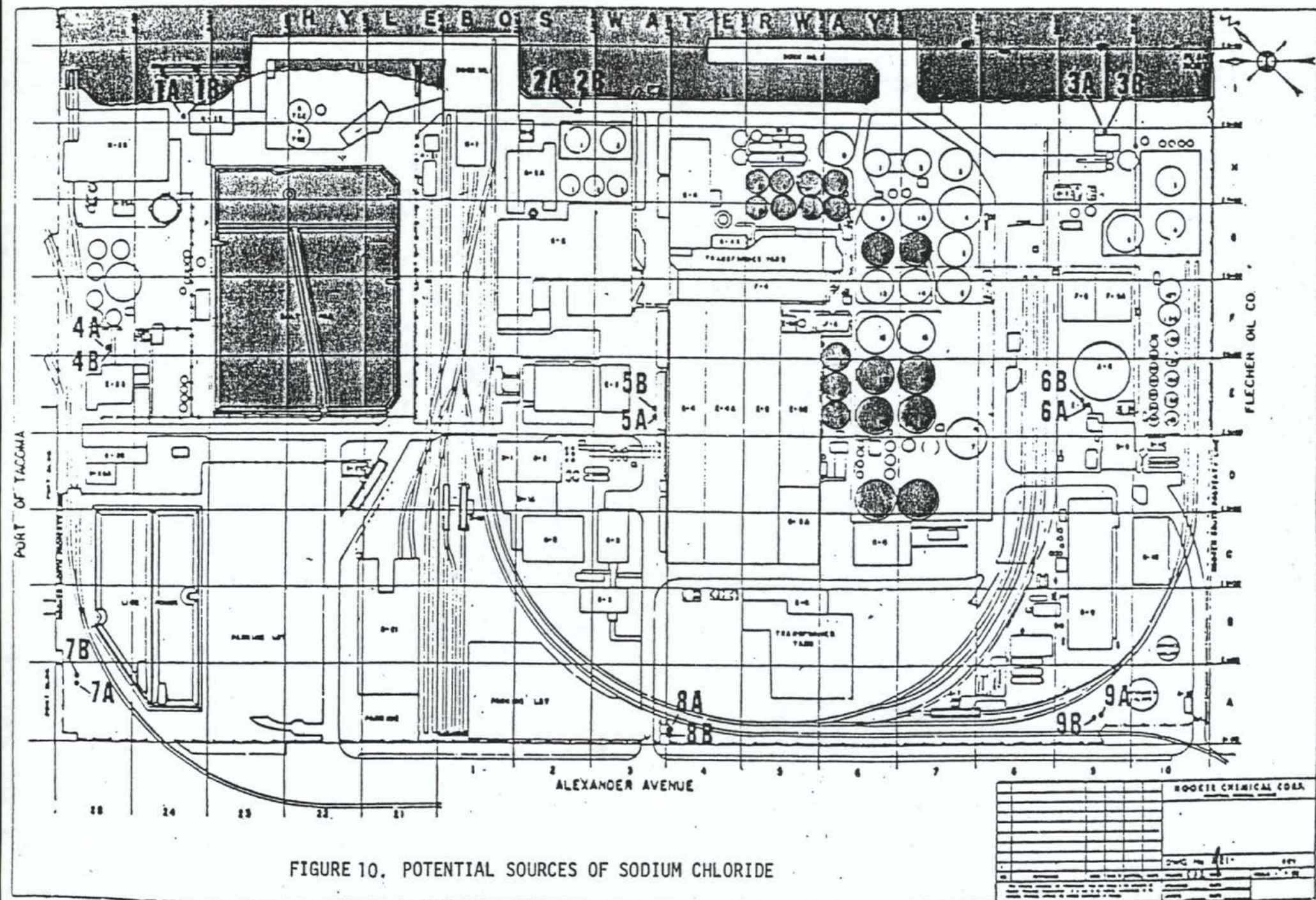


FIGURE 9. POTENTIAL SOURCES OF SODIUM HYDROXIDE



J-864-01



November 30, 1979

Walker Wells, Inc.
501 S. 6th Street, Box 2730
Champaign, IL 61820

Attn: Mr. William Walker

Re: Hydraulic Conductivities and Water Levels
Hooker Chemical Plant
Tacoma, Washington

Gentlemen:

This report presents the results of the hydraulic conductivity tests, water level measurements and survey information for the eighteen sampling wells installed during late August and early September 1979, at the Hooker Chemical Plant located in Tacoma, Washington. These wells were installed to obtain a preliminary assessment of the groundwater flow system beneath the Hooker Chemical Plant, Tacoma, Washington. Siting and installation were directed by William Walker of Walker Wells, Inc. and Mark Utting of Hart-Crowser & Associates, Inc.

Well Description

The design of the sampling wells were produced by William Walker. Basically, there are two types of wells: "shallow" and "deep". The "shallow" wells are approximately 25 feet deep while the "deep" wells penetrate to about 50 feet. The letter "A" in the well numbering system denotes a deep well (i.e., 7A). Shallow wells are indicated by the letter "B". Both types of wells are made of 2 inch schedule 40 PVC pipe. The lower 10 feet of each well(1) is screened with 10 slot (0.010 inch slot size) Hydrophyllic well screen.

The sampling wells were installed by Subterranean, Inc. using a mobile drill B-61 hollow-stem auger. After each well assembly was installed in the drilled hole, the loose sand formation was collapsed around the well with jetted water so that proper sealing and hydrologic coupling to the aquifer could be obtained. The annular space above the collapsed sand was filled with a cement slurry through a "tremmie pipe" placed down to the bottom of the uncollapsed hole. It is our opinion that the sampling wells are properly coupled to the formation at the depth of the well screen and that the filled annulus above this zone is not a major vertical flow path.

(1) Piezometer 4B has 15 feet of well screen.

Hydraulic Conductivity Measurements

Measurements of hydraulic conductivity (permeability to water) were made for the region near the well screen using the well known slug test technique of Hvorslev (1951). In this test several parameters of the soil which is being tested must be established. Among these are the spatial relationship of the well screen to any nearby low-permeability boundaries, soil anisotropy and soil homogeneity. Our analyses are based on observations of soil conditions during drilling which indicated that the soil, generally a medium dense, fine to medium SAND was basically isotropic and homogeneous and that low-permeability boundaries were not too close to the well screen to significantly effect hydraulic conductivity measurements. Thus the Hvorslev equations for "well point-filter in uniform soil" were, in our opinion, applicable.

The Hvorslev method can be used for rising head, falling head and constant head tests. We have used the falling head approach in our analyses. In cases where the soil is isotropic and the well screen is at least four times longer than the diameter of the well boring (such as those at the Hooker site) the falling head equation is:

$$K = \frac{d^2 \ln \left(\frac{2L}{D} \right)}{8 L (\tau_2 - \tau_1)} \ln \frac{h_1}{h_2}$$

Where:

- K = Hydraulic conductivity
- d = Diameter of the well
- D = Diameter of the well boring
- L = Length of the well screen
- t_n = Time of the nth observation
- h_n = Head at the time of the nth observation

In cases where measurements are taken over a long enough time period during which the water level in the well returns to or near to its initial level, the Basic Time Lag equation can be used. In this equation the time required for the falling head to return to 37% of the initial pretest static water level is known as the Basic Time Lag, T. The use of the Basic Time Lag simplifies the Hvorslev equation to:

$$K = \frac{d^2 \ln \left(\frac{2L}{D} \right)}{8 L T}$$

The Basic Time Lag method allows for a graphical check of the falling head slug test data as head versus time should fall on a straight line if plotted semilogarithmically.

We have used the Basic Time Lag method on all but one of our well tests. In one test (4B), the water level fell too rapidly to allow us to collect more than two data points per tests. For this well we have used the falling head test equation, only.

Slug tests were performed in the field by Mark Utting and Matt Dalton of Hart-Crowser & Associates by adding approximately 2 to 3 gallons of water per test to each well. Water was rapidly poured into the well until the well was full and the entrapped air was released. The water level was then allowed to fall while head as a function of time was measured with an electric sounder and a stop watch. Each test was repeated three times or more. The results of the representative tests are shown in Table 1.

Water Level Measurements

Water level measurements were made at both high-high and low-low tides in order to assess the potentiometric surface at both high and low positions. These measurements were made with a chalked blue-steel tape read to the nearest 100th of a foot. The high-high tide readings were taken at approximately 3:44 p.m. on Monday, November 19th, while the low-low tide values were measured at approximately 10:47 p.m., Monday, November 19th. The tidal levels were +11.1 feet and -0.9 feet, respectively.

Survey and Elevation Control

Position and elevation of each sampling well was surveyed by Wilsey & Ham, Inc. They have measured the spatial position of the top of each sampling well referenced to both mean low-low water datum (U.S. Coast and Geodetic Survey monument). The results of their survey are included in Table 2. The approximate locations are shown in Figure 1.

Walker Wells, Inc.
November 30, 1979

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Page 4

The depth to water, depth below ground surface, measuring point distance to ground and time are shown in Table 1.

HART-CROWSER & ASSOCIATES, INC.

Mark G. Utting

MARK G. UTTING
Hydrogeologist

Matthew G. Dalton

MATTHEW G. DALTON
Project Hydrogeologist

John C. Crowser

JOHN C. CROWSER, P.E.
Vice-President



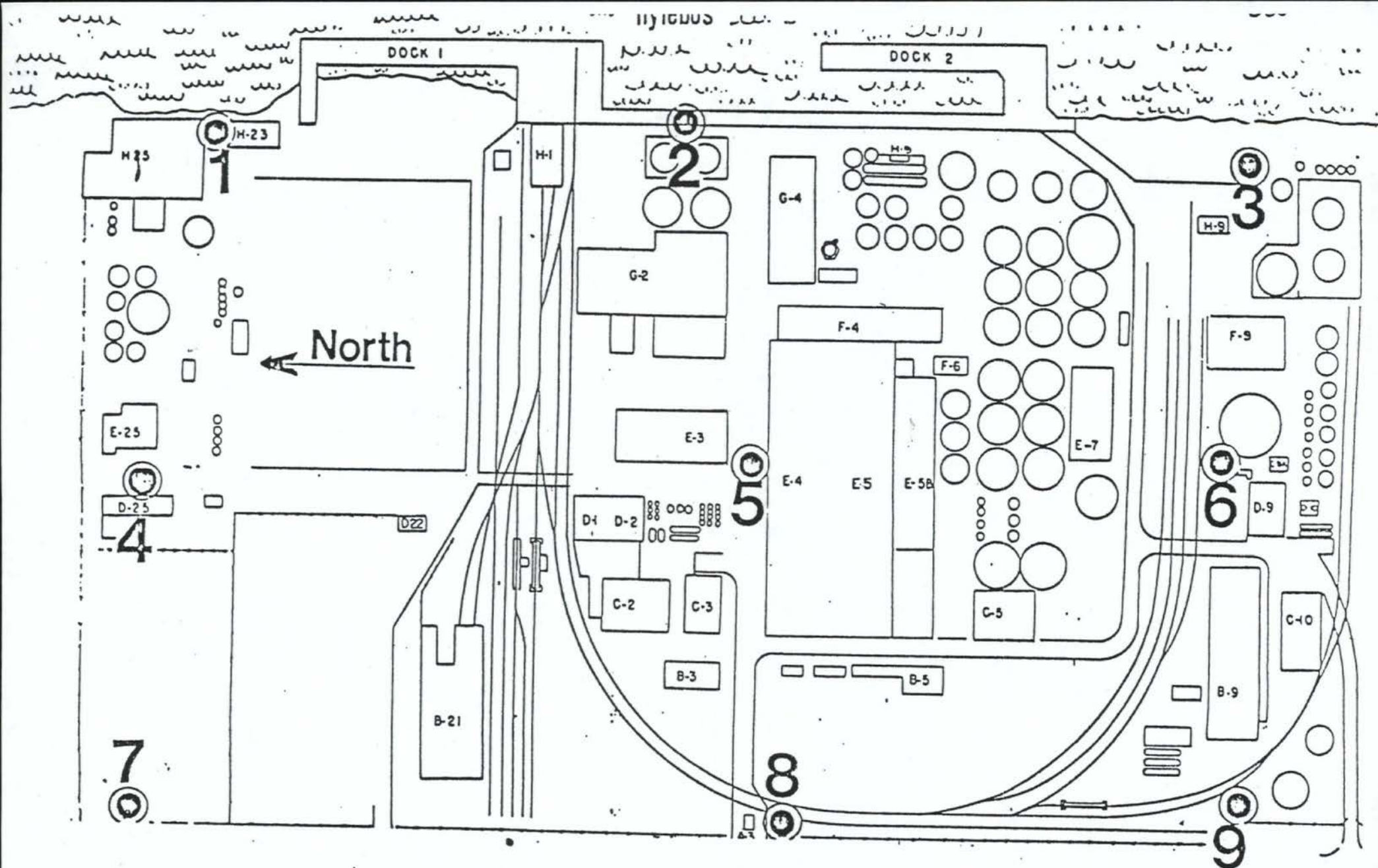


FIGURE 1

WELL SITE LOCATIONS AT THE HOOKER PLANT, TACOMA

TABLE 1

WELL DATA WATER LEVELS

WELL NUMBER	DEPTH BELOW LAND SURFACE	ELEVATIONS (MLLW)			HIGH HIGH TIDE			LOW LOW TIDE			HYDRAULIC CONDUCTIVITY (PERMEABILITY TO WATER)	
		TOP OF CASING	CASING STICK-UP	GROUND SURFACE	DEPTH TO WATER	ELEVATION (MLLW)	TIME PST	DEPTH TO WATER	ELEVATION (MLLW)	TIME PST	CM/SEC	G.P.D./FT ²
1A	49	21.06	3.59	17.4	12.45	8.61	15:52	20.71	0.35	23:30	1.3×10^{-3}	28
1B	25	20.27	2.77	17.5	10.59	9.68	15:52	12.77	7.50	23:23	4.9×10^{-4}	10
2A	49.5	21.67	3.78	17.9	12.27	9.40	16:40	20.87	0.80	23:15	1.9×10^{-3}	40
2B	23.5	20.70	2.77	17.9	10.15	10.55	16:46	13.28	7.42	23:10	2.7×10^{-3}	57
3A	50	22.31	3.56	18.7	12.28	10.03	16:55	19.97	2.34	22:58	1.4×10^{-3}	30
3B	25	21.63	2.77	18.9	11.12	10.51	17:00	12.88	8.75	22:54	1.9×10^{-3}	40
4A	47.5	22.03	3.50	18.5	13.22	8.81	16:05	15.94	6.09	22:11	2.2×10^{-3}	47
4B	23.5	21.16	2.66	18.5	10.95	10.21	16:10	11.54	9.62	22:04	2.6×10^{-3}	55
5A	50	21.54	3.50	18.0	13.72	7.82	16:30	15.91	5.63	22:27	1.6×10^{-3}	34
5B	25	20.70	2.77	17.9	8.03	12.67	16:35	8.02	12.68	22:22	1.4×10^{-3}	30
6A	50	22.65	3.69	18.9	13.72	8.93	17:10	16.08	6.57	22:42	3.3×10^{-3}	70
6B	25	21.81	2.73	19.0	12.61	9.20	17:14	13.73	8.08	22:35	2.7×10^{-3}	57
7A	50	22.67	3.45	19.2	14.72	7.95	15:27	15.20	7.47	00:40	5.0×10^{-4}	11
7B	25	21.82	2.67	19.1	11.22	10.60	15:33	11.25	10.57	00:45	2.3×10^{-3}	49
8A	47	20.28	2.06	18.2	11.12	9.16	16:20	14.15	6.13	00:02	6.7×10^{-3}	142
8B	25	19.85	1.54	18.3	8.44	11.41	16:25	8.52	11.33	23:55	4.0×10^{-3}	85
9A	46	21.65	3.44	18.2	10.23	9.16	17:30	15.51	7.21	23:41	2.7×10^{-3}	57
9B	25	20.71	2.44	18.3	N/A	9.36	N/A	N/A	9.29	N/A	2.4×10^{-3}	51

NOTES: All hydraulic conductivities were calculated with the Basic Time Lag Method except for well 8A in which the Falling Head Method was used.

All distances in feet.

4B re: m. utting LF 12-26-79

Well 9B was partially destroyed. Readings were, therefore, estimated from previous measurements.

TABLE 2

3-216-0401-75

November 27, 1979
Wilsey & Ham, Inc.HOOKER CHEMICAL GROUND WATER SAMPLING STATIONS

SAMPLING WELL NO.	SCREENED DEPTH	WELL DRILL DATE	SAMPLE STA. DATE	M.L.L.W. TO MEASURING PT.	M.L.L.W. TO GROUND SURFACE
1A	39.0' - 49.0'	8-22-79	9-11-79	21.06'	17.3'
1B	15.0' - 25.0'	8-23-79	9-11-79	20.27'	17.7'
2A	39.5' - 49.5'	8-24-79	9-11-79	21.67'	17.8'
2B	13.5' - 23.5'	8-25-79	9-12-79	20.70'	17.9'
3A	40.0' - 50.0'	8-25-79	9-14-79	22.31'	18.7'
3B	15.0' - 25.0'	8-25-79	9-14-79	21.63'	18.8'
4A	37.0' - 47.0'	8-20-79	8-24-79	22.03'	18.5'
4B	8.5' - 23.5'	8-21-79	8-24-79	21.16'	18.5'
5A	40.0' - 50.0'	8-27-79	9-17-79	21.54'	18.0'
5B	15.0' - 25.0'	8-27-79	9-17-79	20.70'	17.9'
6A	40.0' - 50.0'	9-4-79	9-12-79	22.65'	18.8'
6B	15.0' - 25.0'	9-4-79	9-12-79	21.80'	19.0'
7A	40.0' - 50.0'	9-6-79	9-18-79	22.67'	19.2'
7B	15.0' - 25.0'	9-6-79	9-18-79	21.82'	19.1'
8A	37.0' - 47.0'	9-5-79	9-17-79	20.28'	18.2'
8B	13.5' - 23.5'	9-5-79	9-17-79	19.85'	18.3'
9A	37.0' - 47.0'	9-5-79	9-17-79	21.65'	18.2'
9B	13.5' - 23.5'	9-5-79	9-17-79	20.72'	18.2'